Our Case: 10346ROUS01U

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

IN RE APPLICATION OF: David MacDonald DELANEY et al

Serial No: 09/270,733 Examiner: Kevin C. HARPER

Filed: 16 March 1999 Group Art Unit: 2879

Subject: VIRTUAL PRIVATE NETWORKS AND METHODS FOR THEIR OPERATION

Clean Version of Amended Claims

We claim:

1. A method of routing packets through a communications network having a plurality of distinct sets of virtual ports, no virtual port belonging to more than one of the distinct sets, a respective distinct broadcast address being assigned to each distinct set of virtual ports, the method comprising:

assigning a respective egress address to each packet entering the network via an ingress virtual port, the respective egress address corresponding to a respective destination address of the entering packet when a correspondence between the destination address and an egress address is known, and the respective egress address being a broadcast egress address corresponding to the set comprising the ingress virtual port when no correspondence between the destination address and an egress address is known; and

routing the packet according to the respective egress address, said routing being restricted to virtual ports belonging to the distinct set of virtual ports which includes the ingress virtual port.

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2. A method as defined in claim 1, wherein, when the destination address of the packet is a unicast address and a correspondence between the destination address and a unicast egress address is known:

the step of assigning an egress address comprises assigning the unicast egress address, said unicast egress address corresponding to an egress virtual port belonging to the distinct set of virtual ports which includes the ingress virtual port, the destination address being accessible from said egress virtual port; and

the step of routing the packet comprises routing the packet to said egress virtual port.

3. A method as defined in claim 1, wherein, when the destination address of the packet is a unicast address and no correspondence between the destination address and an egress address is known:

the step of assigning an egress address comprises assigning a broadcast egress address corresponding to the distinct set of virtual ports which includes the ingress virtual port; and

the step of routing the packet comprises routing the packet to each virtual port, other than the ingress virtual port, of the distinct set of virtual ports which includes the ingress virtual port.

4. A method as defined in claim 1, wherein, when the destination address of the packet is a multicast address:

the step of assigning an egress address comprises assigning a broadcast egress address corresponding to the distinct set of virtual ports which includes the ingress virtual port; and

the step of routing the packet comprises routing the packet to each virtual port of the distinct set of virtual ports which includes the ingress virtual port other than the ingress virtual port.

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5. A method as defined in claim 1, wherein, when the destination address of the packet is a multicast address and a correspondence between the destination address and a multicast egress address is known:

the step of assigning an egress address comprises assigning the multicast egress address, said multicast egress address corresponding to a plurality of virtual ports belonging to the distinct set of virtual ports which includes the ingress virtual port; and

the step of routing the packet comprises routing the packet to each virtual port of said plurality of virtual ports belonging to the distinct set of virtual ports which includes the ingress virtual port.

6. A method as defined in claim 1, further comprising:

assigning a respective ingress address to each packet entering the network, the respective ingress address corresponding to a virtual port via which the packet enters the network;

using the assigned ingress addresses to populate address association tables; and

using the address association tables to determine correspondences between destination addresses and egress addresses.

7. A method as defined in claim 1, further comprising:

adding to each packet entering the network via an ingress virtual port the respective egress address assigned to that packet to provide a corresponding encapsulated packet;

routing the encapsulated packet in the network according to assigned egress address encapsulated in the packet; and

removing from each encapsulated packet received at an egress virtual port of the network the egress address assigned to that packet to provide a decapusulated packet.

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8. A method as defined in claim 7, further comprising:

assigning a respective ingress address to each packet entering the network, the respective ingress address corresponding to the ingress virtual port via which the packet enters the network;

adding the assigned ingress address to each packet entering the network in providing the corresponding encapsulated packet;

maintaining an address association table associated with each virtual port of the network, each address association table mapping each of a plurality of egress addresses to at least one corresponding destination address; and

using the address association tables to determine correspondences between destination addresses and egress addresses, wherein:

on receipt of a packet entering the network via an ingress virtual port, said packet including a source address, an entry is added to the address association table associated with said ingress virtual port when said address association table does not contain the source address in any destination address field of said address association table, said entry comprising the source address in a destination address field and the ingress address in a corresponding egress address field; and

on receipt of an encapsulated packet at a virtual port of the network, said encapsulated packet including a source address and an ingress address, an entry is added to the address association table associated with said virtual port when said address association table does not contain the source address in any destination address field of said address association table, said entry comprising the source address in a destination address field and the ingress address in a corresponding egress address field.

9. A method as defined in claim 1, wherein:

the step of routing the packet according to the respective egress address comprises routing the packet via trunks of the network; and

when the packet is assigned a broadcast egress address corresponding to a distinct set of virtual ports, the step of routing the packet comprises routing the packet via a restricted set of trunks containing only those trunks required to reach virtual ports in the distinct set of virtual ports corresponding to said broadcast egress address.

10. A method as defined in claim 5, wherein:

the step of routing the packet according to the respective egress address comprises routing the packet via trunks of the network; and

when the packet is assigned a multicast egress address corresponding to a plurality of virtual ports in a distinct set of virtual ports, the step of routing the packet comprises routing the packet via a restricted set of trunks containing only those trunks required to reach virtual ports in the plurality of virtual ports corresponding to said multicast egress address.

11. A communications network, comprising:

a plurality of distinct sets of virtual ports, no virtual port belonging to more than one of the distinct sets, and each distinct set being assigned a respective distinct broadcast address;

at least one address assigner operable to assign a respective egress address to each packet entering the network via an ingress virtual port, the respective egress address corresponding to a respective destination address of the entering packet when a correspondence between the destination address and an egress address is known, and the respective egress address being a broadcast egress address corresponding to the set comprising the ingress virtual port when no correspondence between the destination address and an egress address is known; and

at least one router operable to route the packet according to the respective egress address, said routing being restricted to virtual ports

belonging to the distinct set of virtual ports which includes the ingress virtual port.

12. A network as defined in claim 11, wherein, when the destination address of the packet is a unicast address and a correspondence between the destination address and a unicast egress address is known:

each address assigner is operable to assign the unicast egress address, said unicast egress address corresponding to an egress virtual port belonging to the distinct set of virtual ports which includes the ingress virtual port, the destination address being accessible from said egress virtual port; and

each router is operable to route the packet to said egress virtual port.

13. A network as defined in claim 11, wherein, when the destination address of the packet is a unicast address and no correspondence between the destination address and an egress address is known:

each address assigner is operable to assign a broadcast egress address corresponding to the distinct set of virtual ports which includes the ingress virtual port; and

each router is operable to route the packet to each virtual port, other than the ingress virtual port, of the distinct set of virtual ports which includes the ingress virtual port.

14. A network as defined in claim 11, wherein, when the destination address of the packet is a multicast address:

each address assigner is operable to assign a broadcast egress address corresponding to the distinct set of virtual ports which includes the ingress virtual port; and

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each router is operable to route the packet to each virtual port of the distinct set of virtual ports which includes the ingress virtual port other than the ingress virtual port.

15. A network as defined in claim 11, wherein, when the destination address of the packet is a multicast address and a correspondence between the destination address and a multicast egress address is known:

each address assigner is operable to assign the multicast egress address, said multicast egress address corresponding to a plurality of virtual ports belonging to the distinct set of virtual ports which includes the ingress virtual port; and

each router is operable to route the packet to each virtual port of said plurality of virtual ports belonging to the distinct set of virtual ports which includes the ingress virtual port.

16. A network as defined in claim 11, wherein each address assigner comprises an address association table and is operable:

to assign a respective ingress address to each packet entering the network, the respective ingress address corresponding to a virtual port via which the packet enters the network;

to use assigned ingress addresses to populate the address association table; and

to use the address association table to determine correspondences between destination addresses and egress addresses.

17. A network as defined in claim 11, wherein each address assigner comprises:

an encapsulator for adding to each packet entering the network via an ingress virtual port the respective egress address assigned to that packet to provide a corresponding encapsulated packet; and

a decapsulator for removing from each encapsulated packet received at an egress virtual port of the network the egress address assigned to that packet to provide a decapusulated packet.

18. A network as defined in claim 17, wherein each address assigner is operable:

to assign a respective ingress address to each packet entering the network, the respective ingress address corresponding to the ingress virtual port via which the packet enters the network;

to add the assigned ingress address to each packet entering the network in providing the corresponding encapsulated packet;

to maintain an address association table, the address association table mapping each egress address of a plurality of egress addresses to at least one corresponding destination address; and

to use the address association table to determine correspondences between destination addresses and egress addresses, wherein:

on receipt of a packet entering the network via a virtual port corresponding to an ingress address, said packet including a source address, the address assigner is operable to add an entry to the address association table when the address association table does not contain the source address in any destination address field of the address association table, said entry comprising the source address in a destination address field and the ingress address in a corresponding egress address field; and

on receipt of an encapsulated packet at a virtual port of the network, said encapsulated packet including a source address and an ingress address, the address assigner is operable to add an entry to the address association table associated with said virtual port when said address association table does not contain the source address in any destination address field of said address association table, said entry comprising the source address in a destination address field and the ingress address in a corresponding egress address field.

19. A network as defined in claim 11, further comprising a plurality of trunks interconnecting routers of the network, wherein:

each router is operable to route the packet via trunks of the network; and

when the packet is assigned a broadcast egress address corresponding to a distinct set of virtual ports, each router is operable to route the packet via a restricted set of trunks containing only those trunks required to reach virtual ports in the distinct set of virtual ports corresponding to said broadcast egress address.

20. A network as defined in claim 15, further comprising a plurality of trunks interconnecting routers of the network, wherein:

each router is operable to route the packet via trunks of the network; and

when the packet is assigned a multicast egress address corresponding to a plurality of virtual ports in a distinct set of virtual ports, each router is operable to route the packet via a restricted set of trunks containing only those trunks required to reach virtual ports in the plurality of virtual ports corresponding to said multicast egress address.

21. A routing device for a communications network, the routing device comprising:

a plurality of distinct subsets of virtual ports, no virtual port belonging to more than one of the distinct subsets, each distinct subset being a subset of a respective distinct set of virtual ports of the network and each distinct set being assigned a respective distinct broadcast address;

at least one address assigner operable to assign a respective egress address to each packet entering the network via an ingress virtual port of the routing device, the respective egress address corresponding to a respective destination address of the entering packet when a

correspondence between the destination address and an egress address is known, and the respective egress address being a broadcast egress address corresponding to the set comprising the ingress virtual port when no correspondence between the destination address and an egress address is known; and

at least one router operable to route the packet according to the respective egress address, said routing being restricted to virtual ports belonging to the distinct set of virtual ports which includes the ingress virtual port.

22. A routing device as defined in claim 21, wherein, when the destination address of the packet is a unicast address and a correspondence between the destination address and a unicast egress address is known:

each address assigner is operable to assign the unicast egress address, said unicast egress address corresponding to an egress virtual port belonging to the distinct set of virtual ports which includes the ingress virtual port, the destination address being accessible from said egress virtual port; and

each router is operable to route the packet to said egress virtual port.

23. A routing device as defined in claim 21, wherein, when the destination address of the packet is a unicast address and no correspondence between the destination address and an egress address is known:

each address assigner is operable to assign a broadcast egress address corresponding to the distinct set of virtual ports which includes the ingress virtual port; and

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each router is operable to route the packet to each virtual port of the distinct set of virtual ports which includes the ingress virtual port other than the ingress virtual port.

24. A routing device as defined in claim 21, wherein, when the destination address of the packet is a multicast address:

each address assigner is operable to assign a broadcast egress address corresponding to the distinct set of virtual ports which includes the ingress virtual port; and

each router is operable to route the packet to each virtual port of the distinct set of virtual ports which includes the ingress virtual port other than the ingress virtual port.

25. A routing device as defined in claim 21, wherein, when the destination address of the packet is a multicast address and a correspondence between the destination address and a multicast egress address is known:

each address assigner is operable to assign the multicast egress address, said multicast egress address corresponding to a plurality of virtual ports belonging to the distinct set of virtual ports which includes the ingress virtual port; and

each router is operable to route the packet to each virtual port of said plurality of virtual ports belonging to the distinct set of virtual ports which includes the ingress virtual port.

26. A routing device as defined in claim 21, wherein each address assigner comprises an address association table and is operable:

to assign a respective ingress address to each packet entering the network, the respective ingress address corresponding to a virtual port via which the packet enters the network;

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to use assigned ingress addresses to populate the address association table; and

to use the address association table to determine correspondences between destination addresses and egress addresses.

27. A routing device as defined in claim 21, wherein each address assigner comprises:

an encapsulator for adding to each packet entering the network via an ingress virtual port the respective egress address assigned to that packet to provide a corresponding encapsulated packet; and

a decapsulator for removing from each encapsulated packet received at an egress virtual port of the network the egress address assigned to that packet to provide a decapusulated packet.

28. A routing device as defined in claim 27, wherein each address assigner is operable:

to assign a respective ingress address to each packet entering the network, the respective ingress address corresponding to the ingress virtual port via which the packet enters the network;

to add the assigned ingress address to each packet entering the network in providing the corresponding encapsulated packet;

to maintain an address association table, the address association table mapping each of a plurality of egress addresses to at least one corresponding destination address; and

to use the address association table to determine correspondences between destination addresses and egress addresses, wherein:

on receipt of a packet entering the network via a virtual port associated with an ingress address, said packet including a source address, the address assigner is operable to add an entry to the address association table when the address association table does not contain the source address in any destination address field of the address association table,

said entry comprising the source address in a destination address field and the ingress address in a corresponding egress address field; and

on receipt of an encapsulated packet via a virtual port of the network, said encapsulated packet including a source address and an ingress address, the address assigner is operable to add an entry to the address association table associated with said virtual port when said address association table does not contain the source address in any destination address field of said address association table, said entry comprising the source address in a destination address field and the ingress address in a corresponding egress address field.

29. A routing device as defined in claim 21, wherein:

each router is operable to route the packet via trunks of the network; and

when the packet is assigned a broadcast egress address corresponding to a distinct set of virtual ports, each router is operable to route the packet via a restricted set of trunks containing only those trunks required to reach virtual ports in the distinct set of virtual ports corresponding to said broadcast egress address.

30. A routing device as defined in claim 25, wherein:

each router is operable to route the packet via trunks of the network; and

when the packet is assigned a multicast egress address corresponding to a plurality of virtual ports in a distinct set of virtual ports, each router is operable to route the packet via a restricted set of trunks containing only those trunks required to reach virtual ports in the plurality of virtual ports corresponding to said multicast egress address.

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31. A routing device as defined in claim 28, wherein each router provides IEEE 802.1 switching functionality adapted to packets encapsulated with ingress and egress addresses.

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32. A routing device for a communications network comprising:

a plurality of distinct subsets of virtual ports, no virtual port belonging to more than one of the distinct subsets, each distinct subset being a subset of a respective distinct set of virtual ports of the network and each distinct set being assigned a respective distinct broadcast address;

a respective address assigner for each distinct subset of virtual ports, each address assigner being connected between to its respective distinct subset of virtual ports and a router of the routing device being operable:

to assign a respective egress address to each packet entering the network via an ingress virtual port of the routing device, the respective egress address corresponding to a respective destination address of the entering packet when a correspondence between the destination address and an egress address is known, and the respective egress address being a broadcast egress address corresponding to the set of comprising the ingress virtual port when no correspondence between the destination address and an egress address is known; and

to assign a respective ingress address to each packet entering the network, the respective ingress address corresponding to the ingress virtual port via which the packet enters the network;

each address assigner comprising:

an encapsulator for adding to each packet entering the network via an ingress virtual port the respective egress address and the respective ingress address assigned to that packet to provide a corresponding encapsulated packet; and

a decapsulator for removing from each encapsulated packet received at an egress virtual port of the network the egress address assigned to that packet to provide a decapsulated packet; and

at least one router connected to the address assigners and operable to route the packet according to the egress address, said routing being restricted to virtual ports belonging to the distinct set of virtual ports which includes the ingress virtual port.

33. A routing device as defined in claim 32, further comprising a switching element connected between at least one address assigner and its respective distinct subset of virtual ports, said switching element being operable to multiplex the virtual ports of the respective distinct subset of virtual ports onto the address assigner.

34. A routing device as defined in claim 33, wherein:

each switching element provides IEEE 802.1 switching functionality; and

each router provides IEEE 802.1 switching functionality adapted to packets encapsulated with ingress and egress addresses.

35. A routing device as defined in claim 32, further comprising a plurality of VLAN demultiplexers connected to the router, each VLAN demultiplexer being connected between the router and a respective plurality of the address assigners, each VLAN demultiplexer being associated with a respective egress address and being operable to route an encapsulated packet from the router to an address assigner associated with the ingress address of the encapsulated packet such that all encapsulated packets having a common egress address and an ingress address corresponding to a virtual port in a particular set of the distinct sets of virtual ports are routed to an address assigner associated with that egress address and that particular distinct set of virtual ports.

36. A routing device as defined in claim 35, further comprising:

a respective VLAN translator connected to each address assigner that is connected to the VLAN demultiplexer, each VLAN translator being operable to apply a respective VLAN identifier to packets received from its respective address assigner; and

a router demultiplexer connected to a plurality of the VLAN translators for routing packets received from an external router to a VLAN translator selected according to VLAN identifiers of the packets received from the external router.

37. A routing device as defined in claim 35, further comprising a respective virtual private router connected to each address assigner that is connected to a VLAN demultiplexer.

38. A routing device as defined in claim 37, further comprising a respective network address translator connected to each virtual private router for translating addresses between a respective first address space used by its virtual private router and a second address space used by an Internet router.

39. A routing device as defined in claim 38, further comprising an Internet router connected to the network address translators.

40. A routing device as defined in claim 35, further comprising:

an MPLS switch, the MPLS switch being operable to route packets between an Internet router and address assigners selected according to MPLS labels of the packets; and

a respective MPLS converter connected between each address assigner that is connected to a VLAN demultiplexer and the MPLS switch, each MPLS converter:

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being operable to apply a respective MPLS label to each packet received from its respective address assigner, said MPLS label being uniquely associated with the MPLS converter; and

being operable to remove MPLS labels from packets received from the MPLS switch.

41. A method of routing packets through a communications network having a plurality of distinct sets of virtual ports, no virtual port belonging to more than one of the distinct sets, a respective distinct broadcast address being assigned to each distinct set of virtual ports, the method comprising:

assigning a respective egress address to each packet entering the network via an ingress virtual port, the respective egress address corresponding to a respective destination address of the entering packet when a correspondence between the destination address and an egress address is known, and the respective egress address being a broadcast address corresponding to the set comprising the ingress virtual port when no correspondence between the destination address and an egress address is known;

routing the packet according to the respective egress address, said routing being restricted to virtual ports belonging to the distinct set of virtual ports which includes the ingress virtual port; and

routing an encapsulated packet received from the network to an address assigner selected according to the ingress address and the egress address of the encapsulated packet such that all encapsulated packets having a common egress address and an ingress address corresponding to a virtual port in a particular set of the distinct sets of virtual ports are routed to an address assigner associated with that egress address and that particular distinct set of virtual ports.

42. A method as defined in claim 41, further comprising:

applying a respective VLAN identifier to packets leaving the network from a respective address assigner; and

routing packets received from an external router to an address assigner selected according to VLAN identifiers of the packets received from the external router.

43. A method as defined in claim 41, further comprising:

applying a respective MPLS label to packets leaving the network from an address assigner, said MPLS label being uniquely associated with said address assigner;

routing packets between an Internet router and address assigners according to MPLS labels of the packets; and

removing MPLS labels from packets received from the Internet router.

44. A method as defined in claim 41, further comprising:

applying a respective identifier to packets leaving the network from an address assigner, said identifier being uniquely associated with said address assigner; and

routing packets into and out of the network according to their respective identifiers.

45. A method as defined in claim 1, wherein at least one physical port of the network maps one-to-one onto a corresponding virtual port of network, said physical port and said corresponding virtual port being associated with a respective distinct physical address.

46. A method as defined in claim 1, wherein at least one physical port of the network maps onto a corresponding plurality of virtual ports of the network, said physical port being associated with a respective

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distinct physical address, and each virtual port of said corresponding plurality of virtual ports being associated with a respective distinct combination of said physical address and a respective virtual network identifier.

47. A network as defined in claim 11, wherein at least one physical port of the network maps one-to-one onto a corresponding virtual port of network, said physical port and said corresponding virtual port being associated with a respective distinct physical address.

48. A network as defined in claim 11, wherein at least one physical port of the network maps onto a corresponding plurality of virtual ports of the network, said physical port being associated with a respective distinct physical address, and each virtual port of said corresponding plurality of virtual ports being associated with a respective distinct combination of said physical address and a respective virtual network identifier.

49. A routing device as defined in claim 21, wherein at least one physical port of the routing device maps one-to-one onto a corresponding virtual port of routing device, said physical port and said corresponding virtual port being associated with a respective distinct physical address.

50. A routing device as defined in claim 21, wherein at least one physical port of the routing device maps onto a corresponding plurality of virtual ports of the routing device, said physical port being associated with a respective distinct physical address, and each virtual port of said corresponding plurality of virtual ports being associated with a respective distinct combination of said physical address and a respective virtual network identifier.